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Factors affecting the ability of sheep to rest during time in markets in Great Britain

Running title: The ability of sheep to rest at market

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Abstract

In Great Britain more than 11 million animals are transported to or from livestock markets annually. Time spent at markets is considered by Defra (Department of environment, food and rural affairs) to be 'neutral time', i.e potentially a rest period. However, sheep in markets are subject to many potential stressors, which may prevent them resting. Lying and ruminating behaviours were analysed from 1,638 behavioural scans of sheep in 279 pens in 23 markets across Great Britain. Likelihood of observing ≥ 1 animals lying down during a scan decreased as stocking density and activity outside the pen increased. Proportion of animals observed lying in a pen (when at least one animal was lying) increased as group size and stocking rate decreased. Likelihood of observing ≥ 1 animals ruminating increased when there was no activity around the pen, and as number of sheep in the pen increased. Proportion of animals observed ruminating in a pen (when at least one animal was ruminating) increased as stocking rate, number of sheep in the pen and activity outside the pen decreased. Proportion of sheep ruminating was greater where there was no activity, compared with where there was activity outside the pen. We suggest that in order to allow higher quality rest periods for sheep in markets then markets should be organised so that activity around the pen is minimised e.g. by filling the market from back to front so that, once penned, sheep are not passed repeatedly. Stocking densities should also be low enough to allow animals to lie if they wish, while groups sizes should not be so low as to increase fear responses.

Keywords: animal welfare, sheep, markets, auctions, behaviour, transport

Introduction

Current legislation in Europe (Council Regulation (EC) No. 1/2005) requires that sheep transported commercially in basic standard vehicles on journeys of more than 65km, are not transported for longer than eight hours. Any single journey of over 8 hours would require vehicles used to be of a higher standard, and statutory journey time limits and rest periods

would need to be observed. Because of difficulties observing and enforcing journey time rules for livestock both entering and leaving livestock markets, the time spent in markets is currently considered by Defra (Department of environment, food and rural affairs) to be ‘neutral time’ (potentially a rest period) (Defra 2011b). In Great Britain (GB) large numbers of sheep are transported annually: 41 million sheep were moved by road in 2010, and 38 million in 2011 (Knowles et al 2013). The sheep farming industry in GB is such that animals are frequently moved from farm to market either to be sold on for fattening/overwintering on other farms, or to be sold for slaughter. Thus large numbers of animals spend time in markets during their lives; 15% of animals moved were travelling to or from markets during 2010 and 2011, which represents more than 11 million animals (data extracted from the Animal Movement Licensing System, Scottish Animal Movements System, and Welsh animal Movement Licensing System, via the Rapid analysis and Detection of Animal-Related Risks [RADAR] system, (Defra 2011a)).

In order for ‘neutral’ time in markets to be equated with a genuine period of rest, we assume that sheep must experience a period when they are able to maintain a comfortable physical state, without disturbance from stressors around them. To some extent this is provided for by the Welfare of Animals in Markets Order 1990, which stipulates, amongst other things, that for adult sheep: pens must be of a suitable size; adequate water must be provided as often as necessary to prevent thirst; sufficient feed must be provided by the owner of the animal if kept overnight (or at least once every 12h, from arrival in market); lighting must be adequate for animals to be inspected, fed and watered. However, research suggests there may be some adverse effects for journeys which include a market stop. Kim et al (1994) observed sheep, in the 2h following arrival, in lairage at a slaughterhouse; they found that sheep from markets lay down sooner than those which came direct from farm, perhaps suggesting those sheep from markets were more in need of rest. Aside from the extra loafing and unloaded necessitated by

a market stop, during time spent at markets livestock may experience a number of potential stressors. Cockram (2004) reviewed physiological and behavioural responses of sheep to a number of environmental conditions and changes, many or all of which may be found in markets. Those that elicited a response included: unfamiliar surroundings; contact with unfamiliar sheep; small group sizes or isolation; extremes of temperature; handling; and disturbances from humans nearby. Sheep in markets may also experience restriction of feed and water, as well as temperature variation.

Silanikove (2000) reviewed the effects of heat stress on sheep and found that the critical point at which thermal stress occurs is around 24-26°C and may be marked panting (50-60 breaths per minute, compared to a rate of 19-20 breaths per minute for sheep in a thermoneutral state (Hales 1973)). Mean maximum temperatures for July and August between 1981 and 2010 exceeded 22°C (UK Met Office 2014). Therefore it is possible that, even in the UK, temperatures may become aversive for sheep. This may be especially true in markets with large numbers of animals housed together. Paranhos Da Costa (1992) examined ewes under one year old in a climatic chamber at temperatures between 24°C and 44°C; even at the lower temperatures in that range time spent eating, standing up and ruminating decreased, while time spent drinking and lying down increased. Therefore, to fulfil the requirements for neutral time discussed above, is important that sheep are able to moderate their behaviour to cope with temperatures in this range and maintain a comfortable physical state.

Management practices in markets may affect the ability of sheep to rest and perform normal behaviours. These include stocking density; Kim et al (1994) examined the behaviour of 34 groups of sheep in lairage before slaughter (an environment quite similar to that in market) and found that more than 1m² was required per sheep before more than two-thirds of the animals in a pen would lie down. In the same study human disturbances in the passageways were also associated with a decreased likelihood of sheep lying during human disturbances. In addition

isolation, group size and exposure to humans may impact upon the animals' ability to rest and perform normal behaviours. Baldock and Sibly (1990) found that both isolation of sheep and subsequent introduction to a new flock several days later were associated with increases in heart rate and vocalisation. Furthermore, in a different group of sheep, approach by a human was associated with increased heart rates. Cockram et al (1994) compared the time spent ruminating and lying or resting with eyes closed of two groups of five sheep, isolated for repeated 24h periods, with that in a control group of five sheep, housed together throughout the experimental period. Proportion of time engaged in both behaviours was lower for isolated animals than for animals housed in groups. In addition plasma concentrations of cortisol and prolactin were higher during isolation. When 46 sheep housed in pairs were compared with 40 sheep housed in four groups, all at the same stocking density, Leme et al (2013) found that those in groups of two were less likely to lie down.

The aim of this study was to investigate whether time spent in markets (so-called 'neutral' time) allowed sheep to genuinely rest during this time. Thus we aimed to investigate both whether the market environment provided the conditions necessary for this and the impact of the market environment on the behaviour of animals within. To this end we observed the behaviour of animals in market situations. We recorded behaviours which may be indicative of the animals' ability to rest and perform normal behaviour (allowing them to adjust to their environment) whilst in the market. We recorded resting behaviour (lying and 'resting with eyes closed'). We recorded sucking and nibbling at pen fittings, since this may indicate thirst or hunger in young animals (e.g. non-nutritive sucking and cross sucking in calves, de Paula Vieira et al 2008, Jung & Lidifors 2001). The majority of animals observed in this study were new season lambs, and thus less than a year old, and it is possible that these behaviours could continue to indicate hunger or thirst in these older animals. All of these measures may provide information on the animals' ability to maintain a comfortable physical state. We also recorded

vocalisation and rumination behaviours, which previous studies have suggested may be affected if the sheep found the level of activity around them stressful or aversive (Baldock & Sibley 1990, Cockram et al 2004, Cockram et al 1994, Romeyer & Bouissou 1992). We investigated the relationships between these behaviours and a wide variety of aspects of market environment to discover firstly, whether resting/normal behaviour appeared to be affected by any particular aspects of the market environment, and secondly whether animals' reaction to the market environment suggested that they found them stressful or aversive. In addition we interviewed auctioneers; it is known that stockperson actions and attitudes are associated with animal welfare, thus the way that market staff interact with the animals and view their experiences in market could have a significant impact on the welfare of those animals (Bovin et al 2003).

Materials and Methods

There are 84 permanent markets in England, 35 in Wales, and 32 in Scotland (pers. Comm. Christopher Dodds, Livestock Auctioneers Association). Of those we surveyed 23 markets, which have a combined estimated throughput of approximately 1.4 million animals per year, or around 13% of the total market throughput in GB. Seven of the markets were in Wales, two in Scotland and the remainder in western England and the midlands. Each of the 23 markets was contacted by one of four experienced staff, and agreement to visit the market was obtained. All markets were visited once, and all staff involved in the visits were trained by one principal person in initial joint visits to ensure that data recording was consistent. The visiting member of staff arrived at the market to commence behavioural observations at least 2h prior to the start of the auction, and stayed for at least 1h post-sale (or for as long as sheep remained in the market, if the market emptied less than 1h after the sale). Data on design of the market were collected, and environmental measurements were made inside and outside. After the sale, data on facilities and procedures at the market were collected via an interview with the auctioneer.

Behavioural observations and collection of market data

The practicalities of carrying out this survey in commercial market situations meant that we were unable to collect physiological samples, thus our data collection was restricted to behavioural observations, along with details of facilities and procedures at markets.

Observations of at least 12 separate holding pens of sheep were carried out at each market. The pens were randomly chosen, but comprised a representative sample in all areas of the market (i.e. busier and quieter areas, pens with high and low stocking densities, both inside and outside and to also give a spread of time at the market before the sale commenced). All sheep within a pen came from the same farm; the number of sheep in each pen was recorded, as it varied according to pen size and the number of sheep brought into the market by the farmer. Each pen was observed for one 10 minute period. The observer stood in the raceway, as far away from the pen as possible, whilst retaining a clear view of the sheep. Upon arrival at the pen, the observer stood in their chosen spot for at least two minutes, to allow sheep to become acclimatised to their presence. During the subsequent 10 minute observation period six scan samples, at two minute intervals, were carried out. Observers recorded number of animals lying, ruminating, panting (>60 breaths/minute), 'resting with eyes closed' or sucking/nibbling fittings (mouth around any part of the pen or market fittings). During the observation period all instances of disturbance to the sheep were recorded: either another animal in the same pen mounting or pushing the resting sheep, or human handling the sheep. Incidence of activity outside the pen (humans or animals passing by) were recorded, as were any instances of trampling (one sheep standing on another), feeding, drinking or vocalising. Pens were also scored, using a four-point scoring system (Table 1) for floor cleanliness, sheep calmness, space allowance and the typical level of disturbance throughout the observation period. In addition, pens were scored either 'yes' or 'no' for provision of water.

Where possible visits took place on days of prime stock sales, when observations were concentrated on prime lambs (also termed ‘fat’ or ‘new season lambs’ by the industry) and cull ewes.

Table 1 The scoring systems used to record details of space allowance, floor condition, plus disturbance, and calmness during behavioural observations of selected pens of sheep.

Measure / score	1	2	3	4
Space allowance in pen	All could lie	>2/3 could lie	<1/3 could lie	none could lie
Level of activity around sheep in the pen	No humans or sheep pass or enter pen	Humans or sheep pass by	Handling or ear tag reading from outside the pen	Handling or ear tag reading from inside the pen
Condition of floor in pen	Dry, clean bedding	Dry clean floor (bare)	Wet bedding or floor fairly clean	dirty/wet/bare
Calmness of animals in pen	Majority are calm and several or all are lying and/or ruminating	Most are alert observing and listening to activities in market, <half are lying or ruminating	All are alert most of the time with some vocalising and moving around	None are lying, little or no ruminating - agitated, moving around a lot, vocalising

After the auction, data were gathered on the time of arrival in the market, the origin (address and post code) of the animals in each of the observed pens, the weights of the animals observed, and the type of vehicle used to transport them to the market. The origin of the animals was used to calculate an approximate journey time to the market, while the time of arrival in the market was used to calculate the time in market prior to observations.

Physical measurements

Upon the observer’s arrival at a market a Tinytag Ultra 2 (Gemini Data Loggers, UK) or a HOBO® U12 (Onset, Massachusetts, USA) temperature and humidity logger was placed close to sheep in a representative part of the market, to record temperature at 2 minute intervals. This

was collected at the end of the visit. Air temperature readings inside a covered area and outside were also manually recorded with a Kestrel 4000 Pocket Weather Tracker (Nielsen-Kellerman, Pennsylvania, USA) 3 to 4 times during each visit. A plan of the market was obtained or drawn, and measurements were made of market dimensions. Pen dimensions were measured for pens where behavioural observations were carried out, in order to calculate stocking densities. Records were made of the construction, design and layout of the market, and the location and type of drinkers available. Adequacy of light levels was noted: light levels were scored as poor (dark, with some areas shaded and difficult to see); adequate (light levels sufficient that all animals could be inspected); or good (light levels sufficient that all animals could be inspected and uniform throughout the market). Four-point scores (see Table 2), some of which were based on those described by FAWC (2003), were also used to evaluate the whole market for race floor cleanliness and slipperiness, sheep stress levels from handling, and provision of feed, bedding and water.

Table 2 The scoring systems used to characterise the environment experienced by sheep at markets.

Measure/ score	1	2	3	4
Stress to sheep during handling by lairage staff	Animals moved easily - none or minimal levels of vocal and physical guidance	Animals encouraged to move with occasional use of mild vocal and physical guidance	Frequent shouting at, slapping or goading of animals	Excessive use of sticks shouting, slapping, striking animals. Forcing movements on most/all handling occasions
Access to water¹	Easy access for all	Easy access but may have to wait to drink	Access to drinker difficult (location or high stocking rates)	Insufficient/no drinkers.
Feed/bedding availability in pens	Easy access for all to clean straw/forage	Very limited supply – not all can access at once	Limited or soiled bedding	No feed or edible bedding
Market floor cleanliness¹	Clear of manure	Some manure on floor	Largely covered in manure	Covered in manure/slurry
Market floor slipperiness¹	Dry floor, plenty of grip	Mostly wet but, well grooved/bedding present	Potentially slippery (smooth or wet)	Wet floor, very slippery

¹Includes all pens and raceways and all other areas of the market where sheep may be moved.

Auctioneer interviews

An interview with the market manager/senior partner was conducted to obtain data on: the capacity of the market; numbers of sheep of different classes handled by the market, with seasonal variation; planned stocking rates and variation, including for overnight lairage; policy for providing feed and water; contingency plans for large seasonal sales; operating procedures (indicating where sheep ID is checked, how many separate handling, movement and mixing procedures the sheep undergo and how many people moved the animals). In addition, where possible, estimates were obtained of the cost and feasibility of providing 1 hour of quality resting time, water for all animals and feed for those sheep staying for longer than 8 h in the market. Auctioneers were also asked to provide an opinion on the main issues for sheep welfare at markets.

Analysis

Logistic analysis

Of the behaviours recorded during scans only rumination and lying down were observed at a high enough frequency to warrant statistical analysis. Since these behaviours were still relatively infrequent they were initially modelled using logistic modelling techniques. Binary response variables were created (one for lying and one for rumination), with one datapoint for each scan: a '0' when the behaviour was not observed during that scan, and a '1' when one or more animals were observed performing that behaviour during the scan. Multilevel model logistic models were used to reflect the hierarchical nature of the dataset and account for repeated measures (scans within pens within markets); models were created using Stata 12.0 (StataCorp LP, Texas, USA). All models included a term for a seasonal effect (day of the year) using sine and cosine transformed variables. Explanatory variables included: stocking rate (sheep per square metre) and density (kg per square metre), groups size and space availability in the pen; time in market; journey distances and times; disturbances in and around the pen; environment in the market; and feed and water availability. Journey times and distances were estimated between the postcode of the origin of the sheep and the postcode of the market, for each pen. Estimates were made using an online navigation tool. Incidence of trampling, feeding, drinking and vocalising were calculated per sheep per hour for each observation period, while incidence of disturbance during each observation period was calculated as the number of disturbances per hour (since this was independent of the number of sheep in the pen). To model likelihood of observing lying behaviour during a scan a series of binary logistic regression models was first run examining the relationship with every potential explanatory variable individually; explanatory variables were entered into the model for each response variable one at a time, and those which were significant ($p < 0.1$) were retained for further analysis. All models also included a term for seasonal effect. A backwards regression was then

performed: all significant explanatory variables were then entered together into a single model (with a term for seasonal effect); the variable with the highest p value was then removed and the model re-run. This process was repeated until only significant ($p < 0.05$) explanatory variables remained in the model. Each of the rejected explanatory variables was then re-entered one at a time; any significant variables ($p < 0.05$) were retained. The same process was carried out to model the likelihood of observing rumination during a scan.

Linear analysis

Lying and ruminating behaviours were also subject to linear analysis. In each case scans during which these behaviours were *not observed* were excluded from analysis. Thus a 'lying' variable was created which retained only scans during which one or more animals had been observed lying, and a 'ruminating' variable including only scans during which one or more animals had been observed ruminating. Variables were in the form 'proportion of animals in the pen displaying the behaviour during the scan', and were log transformed. Multilevel linear models were created, reflecting the hierarchy in the data set and account for repeated measures (scans within pens within markets), using the same process to that described above for the logistic regression. Models were first created individually for every potential explanatory variable (including a seasonal effect term); significant explanatory variables ($p < 0.1$) were retained and used to perform a backwards regression. The process continued until only significant explanatory variables remained ($p < 0.05$), and each of the rejected explanatory variables was then re-entered one at a time; any significant variables ($p < 0.05$) were retained.

Results

Across the 23 markets visited capacity ranged between 1,500 and 20,000 animals. Visits took place from June to November 2012. During the visits average temperatures ranged from 8-20°C indoors, and 7-20°C outside. Of the 23 markets visited 19 used natural lighting, some supplementing with electric lighting. All markets were considered to have adequate or good

lighting. All markets used metal rails for pen walls and gates, although some pens also had one or more brick wall. Of the 23 markets the condition of the gates pens and races was considered good in 13/23 markets, average in 9/23 markets, while it was considered poor in the remaining two, due to rusting rails and/or hurdles not being fixed firmly in place (thus either falling down, or moving with the animals inside the pens). In total, five markets employed measures, such as flaps, to prevent legs becoming trapped under partitions. All markets had grooved concrete floors for pens and races, with the exception of one fully outdoor market, which was held on grass and gravel.

Estimates of transport distances could be made for 234 of the 279 pens observed, while transport times were estimated for 223 of the pens observed. Mean transport distance was 22.1 miles (range: 1-298 miles), and mean transport time was 38.0 minutes (range: 2-359 minutes). Arrival times were available for 115 of the pens observed, and sheep had been in the market for an average of 119 minutes (range: 0-730) prior to the time of their observation.

Of the 279 pens observed one contained rams, four contained breeding ewes, four contained store lambs, 13 contained old season lambs (OSL), 71 contained cull ewes, and 186 contained new season lambs (NSL). Average weight data were available for seven pens of OSL (mean = 43.3 kg, standard deviation = 2.7, range: 38.7-46.3kg), 165 pens of OSL (mean = 41.1kg, standard deviation = 5.0, range: 24.9-55kg) and one pen of cull ewes (average weight 44kg).

Market and pen environment

Scores for condition of pens, facility design and layout and the efficiency of handling procedures are summarized in Table 3. The majority of markets had 'better' scores for stressors associated with handling procedures and also for floor cleanliness and slipperiness (scores of ≤ 2 ; FAWC 2003). Feed or edible bedding was provided for animals staying overnight in 22 of the 23 markets surveyed; the remaining market stated that animals kept for several days in the market would be pastured in fields nearby. One market stated that feed/bedding was available

to all animals; two markets provided food to animals staying after the sales (one to any animals remaining after the sale, and one to animals staying for >4h); in one market animals were provided with whatever farmers brought with them; two markets made feed available to some lambs or ewes in milk. All markets provided water for animals staying overnight or for an extended period after the sale. In addition, three markets provided water in the loading/unloading bays for animals to drink as they passed through, and a further two provided water in a small number of pens, which was thus available to sheep that happened to be placed in those pens. All markets had the facilities to provide water if they considered it was required (e.g. portable trough, buckets, etc.).

Table 3 General market facilities and handling. The number of markets with each score for each measure (Underlying scoring: 1=good/available to all, 2=acceptable/available to most, 3=poor/available to few, 4=very poor/available to none – see Table 2 for details). Data were missing from some markets for some measures, thus not all rows add up to 23.

Measure	Score			
	1	2	3	4
Stress of handling	5	16	1	0
Provision of edible bedding or feed	2	4	5	9
Provision of water	1	0	1	17
Floor cleanliness	8	12	2	0
Floor slipperiness	8	12	2	0

In total 279 pens were observed, and 1,638 behavioural scans were carried out. Mean number of sheep in a pen was 12.6 (range: 2-37, n=279), mean stocking rate was 2.8 sheep/m² (range 0.4-7.8, n=276) and density was 118.8 kg/m² (range 32.9-366.6, n=173). All three of these variables were positively correlated: stocking rate increased, in a quadratic relationship, with number of sheep in the pen ($\chi^2 = 192.9$, df = 2, $P < 0.001$, n = 276), and with stocking density ($\chi^2 = 198.7$, df = 2, $P < 0.001$, n = 173). Stocking density increased with number of sheep, in a quadratic relationship ($\chi^2 = 161.9$, df = 2, $P < 0.001$, n = 173)

The environment scores for the pens observed are summarised in Table 4. During the 10 minute observation periods, no pens were observed where the animals had access to water. Overall, 40.4% of pens were estimated to have sufficient space for all animals to lie; in pens scored 1, 2, 3 and 4 for space allowance, stocking rate was 2.0 (CI 1.9, 2.2), 2.8 (CI 2.6, 3.0), 3.7 (CI 3.4, 3.9) and 3.6 (CI 3.2, 4.0), respectively. About half (50.2%) of pens experienced low activity scores due to passers-by, and the majority of pens (85%) contained animals which were relatively calm, with some lying or ruminating. Within holding pens similar proportions of clean, dirty and intermediate floor conditions were seen across the study; statistical analyses showed that higher stocking rates (sheep/m²) were associated with dirtier floors ($\chi^2=10.5$, df 3, $p=0.015$). During our observations, mean rate of human handling of animals in the pen was 0.93 times/h (95% CI: 0.5, 1.4), and while mean rate of activity outside the pen was 8.81 events/h (95% CI: 7.5, 10.1).

Table 4 Pen environment. The percentage of pens across all markets with each score for each measure, where one is best and four is worst (based on FAWC, 2003; see Table 1 for details). The number (n) of pens for which each measure was recorded is given in brackets.

Measure	Score			
	Best	→ Worst		
	1	2	3	4
Space allowance (n=277)	40.4	25.3	24.2	10.1
Level of activity (n=277)	44.0	50.2	4.0	1.8
Condition of floor (n=278)	22.7	30.2	21.2	25.9
Calmness (n=278)	42.5	42.5	14.0	1.1

Behavioural observations and scans

During 279 behavioural observations, 1,638 behavioural scans were carried out; all behaviours were observed infrequently (Table 5). Sheep were observed lying, ‘resting with eyes closed’, sucking/nibbling pen fittings, panting, and ruminating in 590 (36.0%), 65 (4.0%), 94 (5.7%), 82 (5.0%), and 1095 (66.8%) of the behavioural scans, respectively. No animals were observed shivering. Vocalising was recorded at a rate of 0.19 (95% CI: 0.1, 0.3) vocalisations/sheep/h,

with vocalisations occurring during just 21 behavioural observations (18 of which were NSL, two of store lambs and one of cull ewes).

Table 5 Mean and range of percentage of sheep in a pen occupied with each of the recorded behaviours during the behavioural scans, according to class of sheep (NSL – new season lambs; OSL – old season lambs).

Class of sheep	No. of scans	Percentage of animals lying		Percentage of animals ruminating		Percentage of animals panting		Percentage of animals 'resting with eyes closed'		Percentage of animals sucking or nibbling pen fittings	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Breeding ewes	24	1.0	0-4.17	2.9	0-11.8	0	0	0	0	0	0
Cull ewes	419	1.1	0-30	12.3	0-75	0.24	0-16.7	0.1	0-23.1	0	0
NSL	1087	13.8	0-100	18.8	0-100	2.1	0-100	1.1	0-83.3	0.2	0-28.6
OSL	78	11.8	0-76.9	15.4	0-53.8	0	0	0	0	0.2	0-6.7
Rams	6	0	0	0	0	0	0	0	0	0	0
Store lambs	24	9.5	0-40	20.1	0-50	0	0	0	0	0	0

During the 279 behavioural observations no sheep were observed to drink as water was not provided, and very few instances were observed of sheep being trampled, feeding, or having their rest disturbed by other sheep in the same pen (0.01, 0.04, and 0.09 occurrences/sheep/hour, respectively).

Lying behaviour

Logistic analysis

In the final multilevel logistic regression model of lying behaviour ($\chi^2=14.0$, $df=3$, $p=0.003$; Table 6), based on 1638 datapoints, and accounting for time of year, the likelihood of any sheep lying during a behavioural scan decreased as rate of activity outside their pen increased and varied depending on gate condition. Pairwise comparisons revealed that likelihood of observing an animal lying was higher where pen gates were in 'good' condition when compared with 'average' condition. Intraclass correlations were 0.006 and 0.943 for market and pen, respectively.

Table 6 Final logistic regression model of factors associated with likelihood of observing one or more animals lying during a behavioural scan.

Variable	Category	OR	95% CI	χ^2	DF	p
Rate of activity outside the pen	n/a	0.89	0.79, 0.99	4.5	1	0.034
Condition of pen gates	Good	124.28	4.21, 3666.50	7.83	2	0.020
	Poor	8.63	0.06, 183.30			
	Average	Reference category				

When stocking density (kg/m^2) was included in the model described above, a quadratic relationship was identified: likelihood of any sheep lying during a behavioural scan decreased as stocking density increased ($\chi^2=7.13$, df 2, $p=0.028$, $n=1,010$). However, the sample size for the model when stocking density was included was much lower, since weight measurements, and therefore stocking density data, were rarely recorded for cull ewes. Consequently this variable was not included in the final model. It is notable that there was no significant association between likelihood of observing one or more animals lying and either stocking rate or number of sheep in the pen, even when the analysis was restricted to NSL and OSL groups, to match the data available for stocking density.

When journey time from farm to market was included in the final model, above, there was also a tendency for the likelihood of any sheep lying during a behavioural scan to decrease as estimated journey increased (OR=0.96, 95% CI: 0.93, 1.01, $\chi^2=2.85$, df 1, $p=0.091$, $n=1,304$). Sample size for this association was again smaller, due to missing journey time data, therefore this variable was not included in the final model.

Linear analysis

In the final multilevel linear model of proportion of sheep lying, accounting for time of year, and based on 590 datapoints (from 126 pens in 23 markets), there was a quadratic relationship with number of sheep in the pen; when sheep were observed lying during a behavioural scan, a greater proportion was observed to lie in smaller groups ($\chi^2=43.6$, df 2, $p<0.001$). The

proportion of sheep in a pen lying down also increased as stocking rate decreased (sheep/m²; $\chi^2=9.29$, df 1, $p=0.002$). There was no interaction between these variables. Intraclass correlations were 0.103 and 0.826 for market and pen, respectively.

The relationship between animals lying and stocking density was maintained in both logistic and linear regression models when sensitivity tests were performed by removing outliers of stocking density (stocking densities greater than 300 kg/m²).

Rumination behaviour

Logistic analysis

The most commonly observed behaviour was rumination, thus a more robust analysis was possible for this variable. In the final multilevel logistic regression model of rumination behaviour ($\chi^2=27.5$, df=4, $p<0.001$; Table 7), based on 1,630 datapoints, and accounting for time of year sheep were more likely to be observed ruminating when the score for activity around them was low: pairwise comparisons revealed that sheep in pens with no activity (score 1) were 4.1 times more likely to be observed ruminating compared with pens which had activity due to passers-by (score 2), and 11.4 times more likely compared with pens which experienced handling from outside the pen (score 3). Sheep were observed to ruminate in 76% of behaviour scans of pens which had no activity (score 1) and in 61%, 43% and 59% of behaviour scans which had activity due to passers-by, handling from outside the pen, and handling inside the pen (scores 2, 3 and 4, respectively). The likelihood of observing rumination during a behavioural scan also increased as the number of sheep in the pen increased. For every extra sheep in the pen there was a 12% greater chance of observing one or more animals ruminating during a scan. Intraclass correlations were 0.093 and 0.709 for market and pen, respectively.

Table 7 Final logistic regression model of factors associated with likelihood of observing one or more animals ruminating during a behavioural scan.

Variable	Category	OR	95% CI	χ^2	DF	p
Number of sheep in the pen	n/a	1.12	1.10, 1.20	12.2	1	0.001
Level of activity around sheep in the pen	Humans/sheep pass	0.24	0.10, 0.60	13.6	3	0.004
	Handling from outside pen	0.09	0.01, 0.61			
	Handling from inside pen	0.12	0.01, 1.67			
	None	Reference category				

It is notable that, in a model with time of year and level of disturbance, likelihood of observing rumination also increased with stocking density (sheep/m²; OR = 1.76, CI: 1.2, 2.5, $\chi^2=8.9$ p = 0.003); however, stocking density became insignificant with the addition of number of sheep in the pen to the model. There was no significant interaction between these variables.

In a model with time of year, level of disturbance and number of sheep in the pen, we were also less likely to observe one or more animals ruminating when the weather was windy compared with when there was a light breeze (OR = 0.03, 95% CI: 0.0, 0.5, $\chi^2 = 7.74$, df = 2, $P = 0.021$, n = 1,487). Likelihood of observing one or more animals ruminating increased with number of people observed to handle the sheep in the market (OR = 1.10, 95% CI: 1.0, 1.2, $\chi^2 = 5.06$, df = 1, $P = 0.025$, n = 1,395). Neither of these variables were included in the final model since they were missing large numbers of datapoints.

Linear analysis

In the final multilevel linear regression model of proportion of sheep ruminating, which was based on 1,082 datapoints, and accounted for time of year, the proportion of animals ruminating during a behavioural scan increased as stocking rate (sheep per m²; $\chi^2 = 11.6$, df = 1, $P = 0.001$), number of sheep in the pen ($\chi^2 = 27.7$, df = 1, $P < 0.001$), and rate of activity outside the pen ($\chi^2 = 4.58$, df = 1, $P = 0.032$), decreased. The proportion of animals ruminating was also associated with the location of EID tag reading ($\chi^2 = 9.11$, df = 3, $P = 0.028$), the class of sheep

($\chi^2 = 20.6$, $df = 4$, $P < 0.001$), and activity score ($\chi^2 = 10.3$, $df = 3$, $P = 0.016$). The proportion of sheep ruminating was less where sheep ID was checked by market staff in the pen or in the ring compared with in a raceway. The proportion of sheep ruminating was less in: breeding ewes compared with all other categories; cull ewes compared with new and old season lambs; and new season lambs compared with old season lambs. The proportion of sheep ruminating was less in pens with activity due to passers-by (score 2), compared with no activity (score 1). Intraclass correlations were 0.003 and 0.621 for market and pen, respectively.

In a model with the variables above included, the proportion of sheep ruminating was also lower in windy weather conditions ($\chi^2 = 8.51$, $df = 2$, $P = 0.014$, $n = 998$), and increased with the amount of time for which the sheep had been in the market ($\chi^2 = 4.45$, $df = 1$, $P = 0.035$, $n = 404$). There was, however, insufficient data associated with these variables to include them in the final model reported above.

Auctioneer views

Auctioneers were asked to estimate the feasibility of providing water, feed and a rest period (i.e when they could perform maintenance and resting behaviours without being disturbed) of at least 1h, on a scale of 0-10 (zero being easy, and ten, impossible). With regard to provision of water within holding pens, 9/20 auctioneers who answered the question gave scores of eight or more, citing expense, maintenance issues (particularly keeping the supply clean and free of faeces), jostling and fighting for access between sheep, with the potential to cause injury, as major concerns in supplying water. With regard to provision of feed, 7/19 auctioneers who answered the question gave scores of eight or more, with the majority commenting that slaughterhouses would object if animals were provided with feed. Finally, with regard to provision of a rest period 15/23 auctioneers stated that all sheep already had access to a rest period of at least 1h. A further five auctioneers stated that some sheep would have such a rest period depending on when they arrived in the market, and where they were penned. When

asked when rest periods should be allowed ten auctioneers commented that rest periods would have to be (or currently are) before sale, while six considered that rest periods would have to be (or currently are) after sales. Nine auctioneers, of the 15 who made comments, stated that separating resting sheep from non-resting sheep would not be possible.

Opinions as to how sheep welfare could be improved at markets were varied. The most common response was that the market had been designed with welfare in mind and could not be improved, or that inspectors would indicate if any improvement was necessary (6/23). Three felt overhead cover was desirable for slaughter sheep or those staying a long time. Measures to reduce noise levels and echo were thought necessary. Minority opinions included designing races with rounded corners, fans for hot weather, limiting the size of markets (to reduce handler fatigue) and having specific separate lairage areas for sheep staying for more than eight hours in the market.

Discussion

We visited a wide range of markets, across Great Britain, with a variety of capacities. As part of the multilevel modelling process intra-class correlations (IC) were calculated for markets and pens. Generally the IC was low for markets and higher for pens, meaning that there were similarities between animals within pens, but fewer similarities between pens within markets. We generally found pens and races were in good repair, with adequate or good lighting. Floor conditions varied in pens, although slipperiness in the races/aisles was not generally considered to be a problem. Although all markets made water available to animals during extended stays in the market, very few (22%) made water available to some sheep during the course of a normal daytime market stay. Although three markets offered water in loading/unloading bays, few animals would have had the opportunity to drink as they moved through those areas. Furthermore, although all but one market provided feed/bedding for animals staying overnight, just 21.7% of markets provided feed/bedding to animals in the market for shorter periods.

When questioned on the feasibility of providing water to all animals auctioneers cited many difficulties with the provision of water to all animals, while they were concerned that slaughterhouses would object if animals were supplied with feed as this might cause increased gut fill and contamination of the carcase or possibly lead to thirst. However, all markets did have the facility to provide water as necessary in buckets if they deemed it necessary. Sucking and nibbling at pen fittings, which may indicate thirst or hunger in young animals (e.g. non-nutritive sucking and cross sucking in calves, de Paula Vieira et al 2008, Jung & Lidifors 2001), was observed infrequently, thus we found no evidence that many animals were hungry/thirsty in markets.

Panting was used as an indicator of heat stress but was only recorded in 5% of behavioural scans. The temperatures recorded during our observations were not high, reaching a maximum of only 20°C both indoors and out. However, the fact that we did see some panting, even in relatively mild temperatures could have been a result of high stocking densities (although we could not show an association between panting and stocking density in our data, due to the rarity of panting, and missing stocking density data), which would have resulted in higher temperatures immediately around the animals, reduced their convective heat loss and increased conductive heat gain from adjacent animals. In addition high stocking densities may have prevented the performance of thermoregulatory behaviours. Temperatures inside the markets were no lower than 8°C, which is easily tolerated by sheep in fleece and not fasted, especially when kept closely together, so unsurprisingly none were observed shivering or huddling (Alexander 1974).

In order to investigate the ability of sheep to rest during markets we examined the lying behaviour of sheep in markets. We found that as stocking density increased (measured over the range 32.9-366.6 kg/m²) likelihood of observing animals lying down decreased. It is also interesting to note that although stocking density was associated with likelihood of observing

one or more sheep lying, neither stocking rate nor the number of sheep in the pen were significant, even when the same subset of data was examined as was available for stocking density (i.e. NSL and OSL). However, where lying *was* observed, the proportion of animals performing this behaviour decreased as stocking rate increased (range 0.4-7.8 sheep/m²). Kim et al (1994) suggested that a space allowance of 1m² per sheep for most of the sheep within a group to be able to lie down. Mean stocking rate in this study was 2.8 sheep/m², or 0.42 m² per sheep, thus it may be that stocking rates are generally too high to afford all animals the opportunity to lie down, although this was not a concern raised by auctioneers. Indeed just 40% of pens were judged by the observers to allow enough space for all animals to lie down and mean stocking rate in these pens was 2.0 sheep/m² or 0.5 m² per sheep. This was based on whether the observer thought it physically possible for all animals to lie; it may be that actual space requirements for all animals to lie are greater if animals prefer to keep some distance between themselves and their neighbour, which may explain the higher space requirements quoted by Kim et al (1994). Where observers considered that there was space for all animals to lie in this study a mean of 18% of animals were observed lying, compared with an overall mean of 10% of animals lying for all pens. For sheep under 55kg (as were the sheep observed in this study) the required space allowance during transport is 0.2-0.3m² per animal (Defra 2012). Thus mean space allowance in markets exceeded that required during transport; however, our observations suggest that a greater allowance was required for all sheep that may have been motivated to do so, to readily lie in pens at market.

Notably the proportion of animals observed lying down (eyes open), where lying was observed, decreased as the number of animals in the pen group increased. Although number of animals and stocking rate were correlated within this study both remained significant in the model together, and an interaction including these variables was not significant. It may be that number of animals in the pens has a separate effect to stocking rate; for example there may be more

disturbances from other animals in the pen, which prevent animals lying when both group size and stocking rate increase; thus the effects of these variables may be additive. Consequently, it seems that in order to facilitate undisturbed resting behaviour stocking densities/rates and group size in pens may all need to be reduced in some cases.

Sheep were also less likely to be observed lying during a behavioural scan the more activity there was outside their pens. Rates of activity outside pens were high, with pens on average experiencing 9 events outside the pen per hour. This suggests that activity in the market could frequently affect animals' ability to rest. It may be that in order to rest fully sheep require quiet areas with little passing 'traffic'.

We observed very low numbers of animals 'resting with eyes closed', with such animals being recorded in just 4% of scans. This may provide further evidence that sheep are not able to fully rest during markets; however, it is unclear how many animals would normally be resting in this way during the time of day when observations were carried out, mostly during the early morning, so this should be interpreted with caution.

Rumination was examined as it is known to be affected in stressful or aversive situations (Cockram et al 1993, Cockram et al 1996, Cockram et al 1994, Paranhos Da Costa et al 1992). Animals were least likely to be observed ruminating in pens where humans and sheep passed by, or in pens where sheep were handled by people standing outside the pen. Similarly, in pens where rumination was observed during behavioural scans, the proportion of sheep in the pen ruminating increased as rate of activity outside the pen decreased. These findings suggest that even minor disturbance from people and animals outside pens may be aversive or stressful for the animals concerned.

The majority of activity experienced by animals in market was non-invasive: 50% of pens experienced activity due to sheep or humans passing by, while just 4% experienced handling

from outside the pens, and a further 2% from handling inside the pen. The predominant reason for handling from outside the pen was buyers leaning over and feeling the backs of some sheep in the pen, while ear tag reading was the main reason for the handling inside the pen, usually for a brief period of 2-3 minutes per pen. However, we found that the likelihood of observing ruminating during a behavioural scan was reduced even at low levels of activity, with sheep or humans passing by, suggesting the animals found these events stressful or aversive. As rates of activity outside pens were high this may have a significant impact on the ability of animals to rest in markets.

We also found that the likelihood of observing rumination during a behavioural scan increased with the number of animals in the pen. This result should be considered with care; it is possible that this could be an artefact of the data; an increased number of animals leads to an increased chance of observing the behaviour. However, small group size has previously been associated with reduced idle time and lying behaviour (Leme et al 2013). It may be that increased group size reduces the aversiveness of the market situation for sheep. Group size is hard to define in the context of a market environment; although a pen may contain a relatively small group of familiar animals (between 2-37 animals in this study), these groups will be part of a much larger 'flock' within a busy market. Furthermore, this result appears to be in contrast to the results discussed above for lying behaviour, where fewer animals were observed to lie in larger groups. Additionally, where sheep *were* observed ruminating during a behavioural scan, we found that proportion of animals ruminating increased as stocking rate (sheep/m²), and number of sheep in the pen, decreased, in line with the results found for lying behaviour. It may be that there is a trade-off between stocking rate and number of animals, with animals being less stressed by the market environment in larger groups; however, as stocking rate increased with group size, larger groups may also prevent animals lying down to rest where no allowance for extra space is made, as is usually the case. It is clear that further work is required to better

understand the effects of both group size and stocking rate, and their interrelationship, on sheep within the market environment.

Vocalisation was infrequent. Previous studies have recorded increased vocalisation in situations which may be stressful, such as social isolation (Boivin et al 1997, Cockram et al 1994, Lyons et al 1993, Poindron et al 1997) and when presented with a novel object (Romeyer & Bouissou 1992). Therefore, we might have expected high levels of vocalisation if the market situation was stressful. However, other studies have reported decreased vocalisation in the presence of humans (Romeyer & Bouissou 1992), where it has been suggested that such a reduction in vocalisation acts as an anti-predator response. During the market visits it was noted that many of the sheep observed in this study were hill sheep, and thus not habituated to humans. Consequently, in markets, where there were frequently humans nearby it is possible that vocalisation was suppressed as a fear response to the proximity of humans.

There were several other results of interest. The likelihood of observing one or more animal lying down during a scan was higher when pen gates were in good compared with average condition, and likelihood of observing one or more animal ruminating during a scan increased with the number of people that were observed to handle the sheep during their time in market. It is possible that pen gates being in good condition and larger numbers of staff on hand facilitates smoother handling of animals in the market, thereby reducing the stress for the animals concerned. Thus we might expect to see increased resting behaviours such as lying and ruminating. Alternatively the condition of pen gates and number of staff available may act as 'quality' indicators for overall management of the market. However, since this is a correlational study it is difficult to be certain of the causal mechanisms, so these factors would benefit from further study.

Animal Welfare Implications

The majority of auctioneers stated that all or some sheep at their market had already received an undisturbed rest period, either before or after the sale. None identified a need for rest as a welfare concern at markets. However, these results suggest that, under current conditions sheep in markets are not allowed to fully rest; stocking densities and group sizes appear to prevent some animals from lying down, and the level of activity around the animals is sufficient to cause frequent disturbances, with relatively minor activity affecting the behaviour of the animals observed. Thus markets may not always be able to truly provide 'neutral time' when these risk factors are present. Ability to rest may be improved by limiting stocking densities, especially when group sizes are large, and simultaneously taking care not to pen animals in large pens and small groups, thereby reducing stress associated with social isolation. For example, Gonzalez et al (2013) found that focal animals in groups as small as five sheep made fewer attempts to escape their enclosure when compared to single sheep in the same enclosure. Furthermore, sheep penned at lower stocking densities may cope with onward transport to farm or slaughter premises better since, when penned for protracted periods, sheep with sufficient room to move would be able to adapt their behaviour to greater preserve both energy and moisture, regulate body temperature, and to lessen the detrimental effects of transport. More and better rest may be facilitated by managing markets so that there is as little disturbance as possible to sheep during their time in market. Combined observations suggested that in the majority of markets disturbance may be reduced, for example, by filling pens furthest away from the point of entry to the market first, so that, once in their pen, sheep are left undisturbed by the movements of both drovers and other sheep. Some markets restrict the access of the public, including buyers before the auction and this facilitates better rest.

Thus there is scope to make time spent in markets more restful, and thereby improve welfare during transport. However, many auctioneers felt that animal welfare in markets could not be improved, or that inspectors would draw their attention to it, if there was a problem, and did

not see a need to provide further opportunities to rest. Thus reticence amongst market staff may be a barrier to such changes if they do not ‘buy in’ to the reasons for making changes (Whay 2007).

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